Mars Rocks! CT Visualization of Trial-Run Core Sample from the Mars 2020 Program

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5145 Analysis and Test Laboratory
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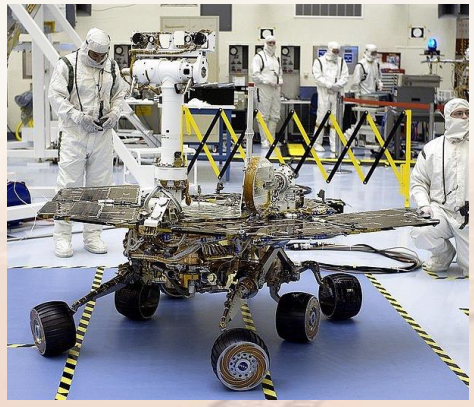
Jet Propulsion Laboratory
California Institute of Technology

The Evolution of Mars Rovers

A brief overview

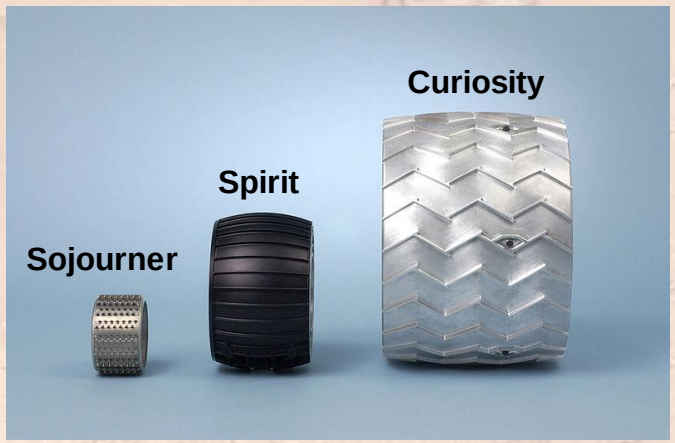
Sojourner
Launch: ‘96
Weight: 25 lbs



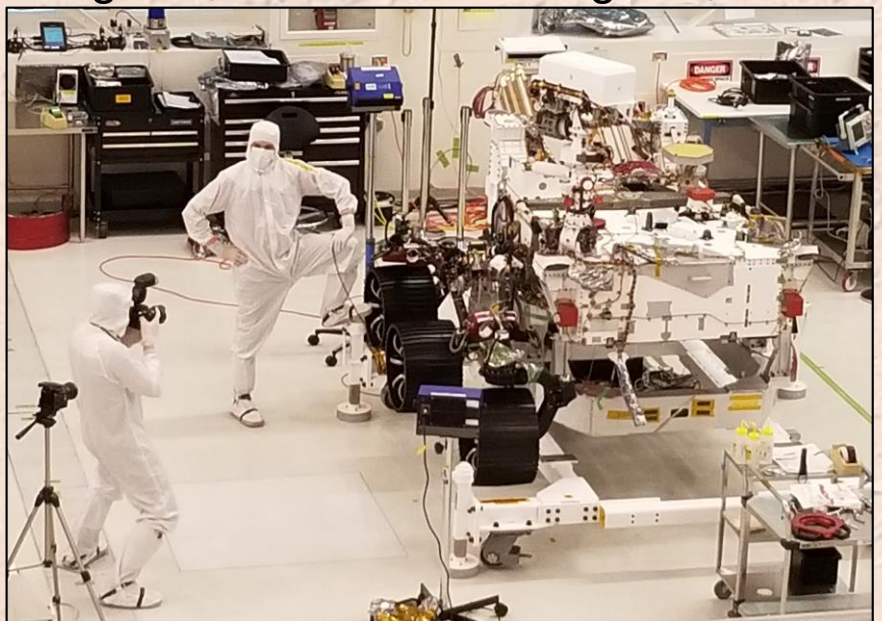
Spirit/Opportunity
Launch: ‘03
Weight: 408 lbs

Curiosity
Launch: ‘11
Weight: 1,982 lbs

M2020
Launch: ‘20
Weight: 2,315 lbs



Images from Wikipedia.org

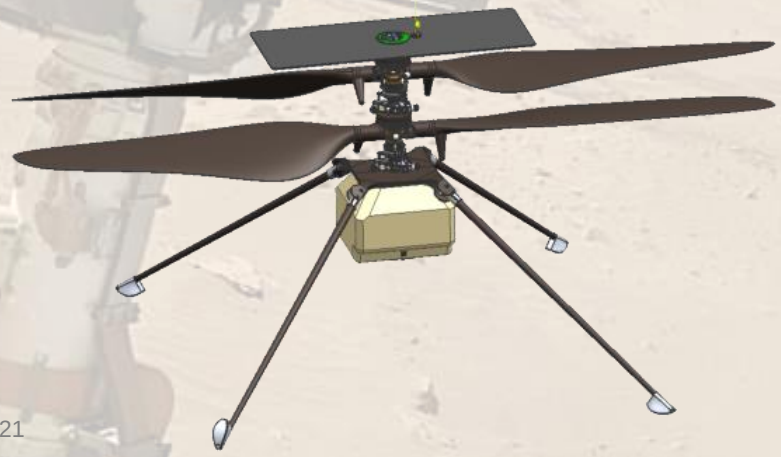


Who is Mars 2020?

A Biologist on Mars

At a glance:

- Improved stereo Mastcam
- SuperCam: builds on Curiousity's ChemCam
- Laser Fluorescence & Raman Spectroscopy
- X-ray Fluorescence Spectroscopy
- Ground-Penetrating Radar
- Weather-Monitoring (temp/humidity/dust)
- Converts CO2 to O2
- More & better engineering/hazcams
- Operational Efficiency Boosted
- Bringing a Friend: Mars Helicopter
- Drilling Core Samples & caching them



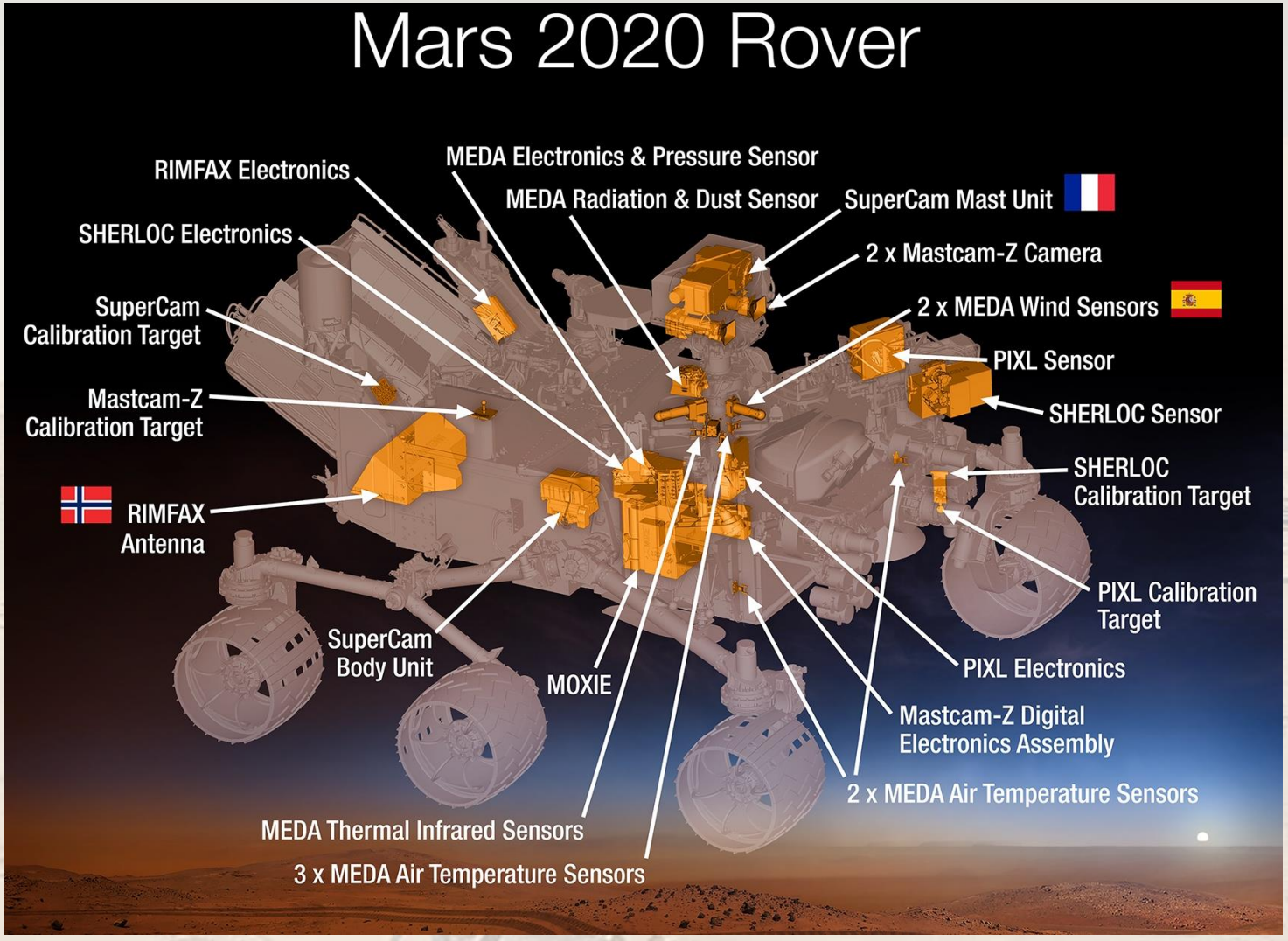
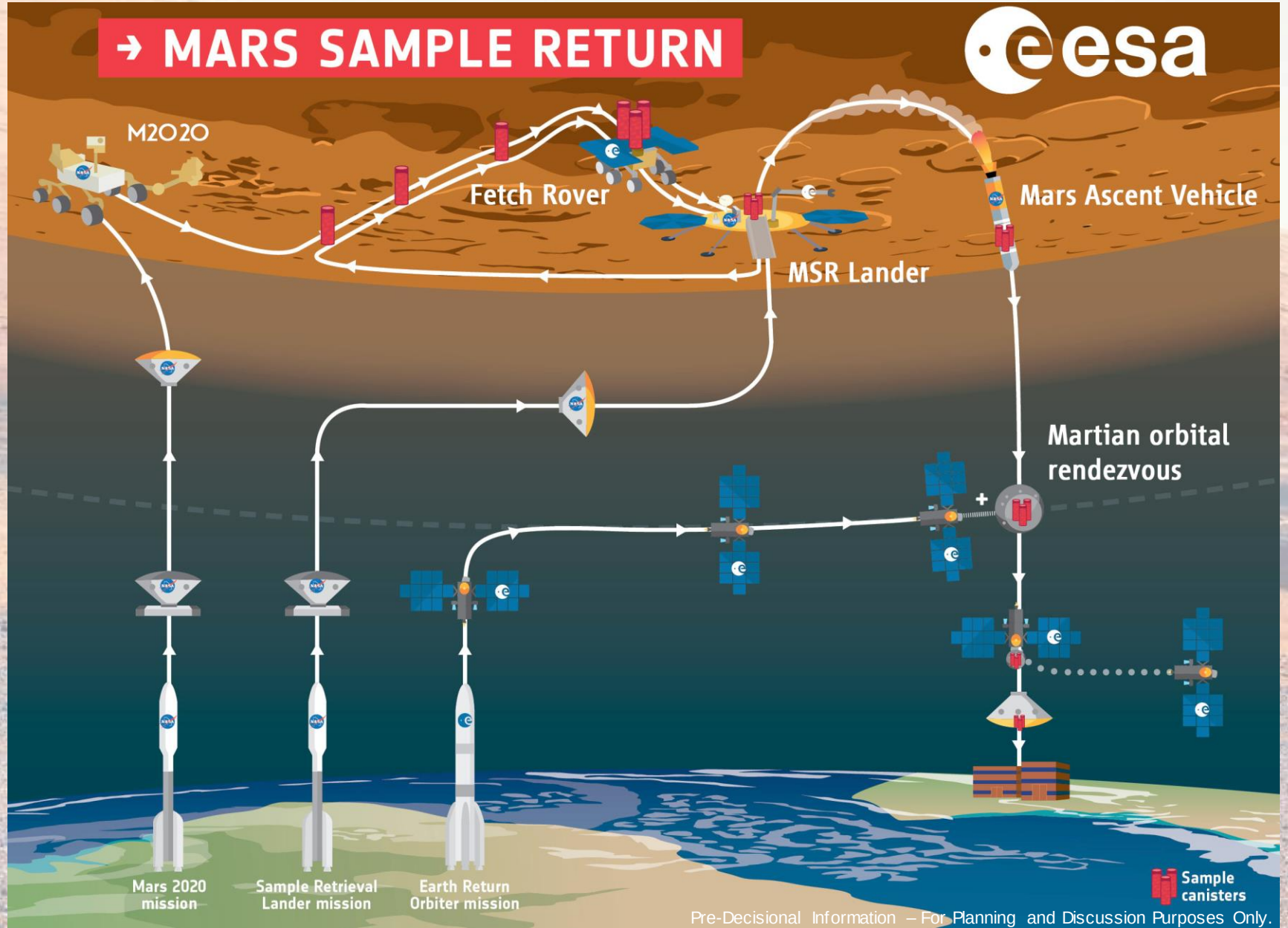


Image from NASA/JPL-Caltech

What is Mars Sample Return?

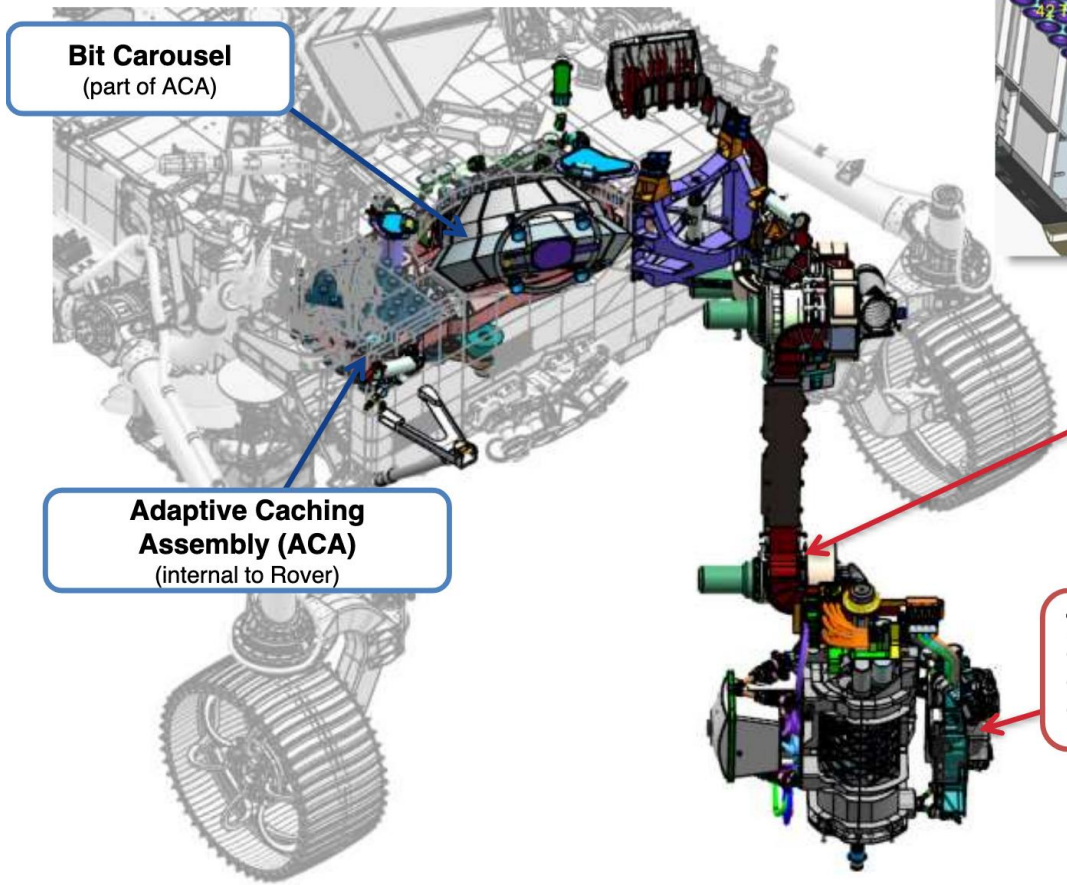
A potential campaign of many “firsts”

Image from ESA / K. Oldenburg

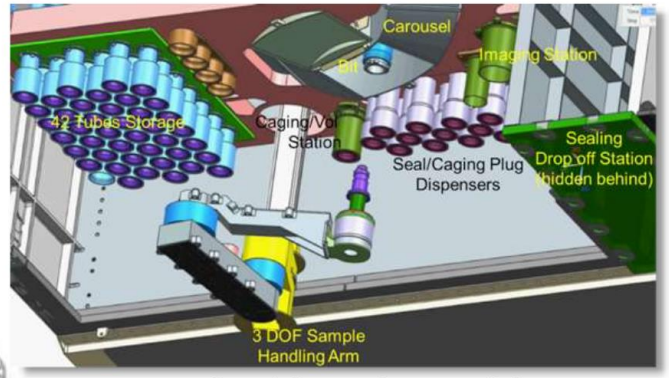


What is the Sample Caching System?

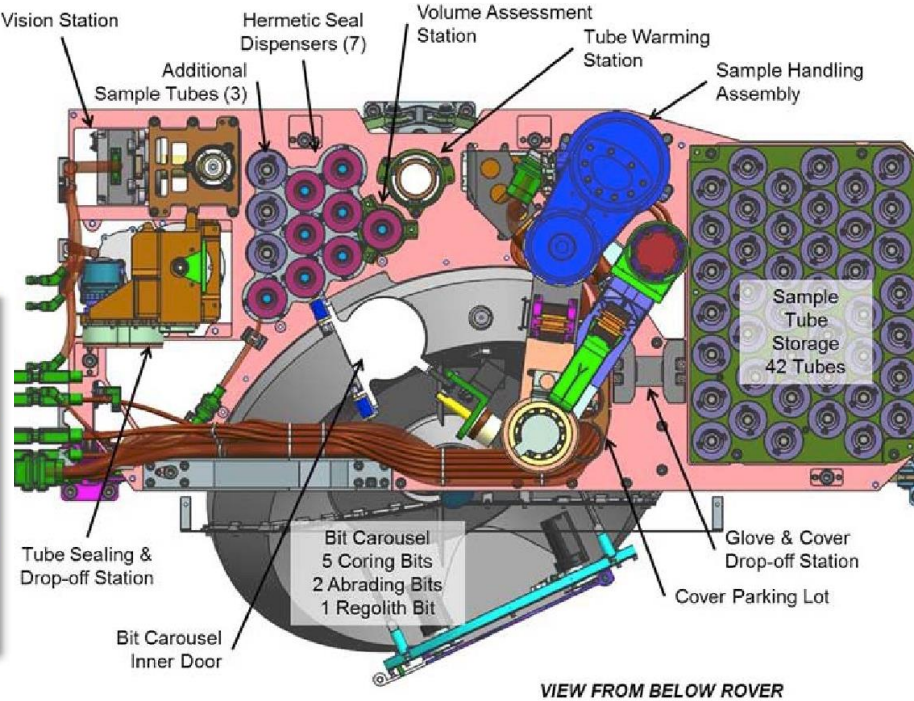
Drills, Seals, and Caches Martian Core Samples



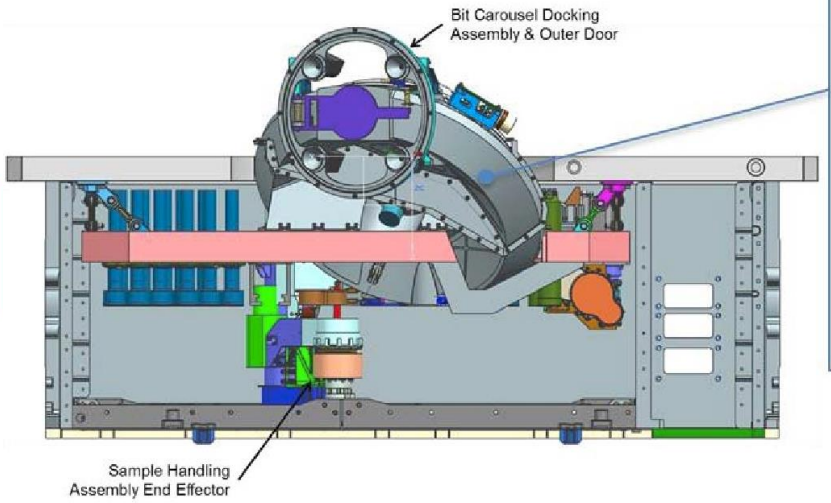
~ 42 sample tubes



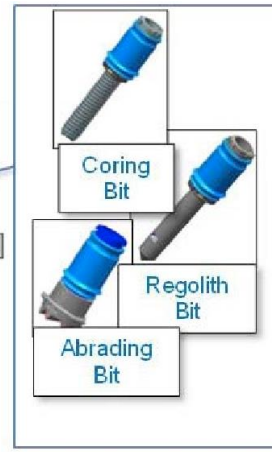
Caching Assembly



VIEW FROM BELOW ROVER



ROVER FRONT
FRONT PANEL REMOVED FROM VIEW



Images from https://sites.nationalacademies.org/cs/groups/ssbsite/documents/webpage/ssb_183746.pdf
https://www.semanticscholar.org/paper/Organic-and-inorganic-contamination-control-for-on-White-Anderson/f1895702a006c2ac4762f2605f99a76bb9810a4b

Sample Caching Tube

Optical Images

Isometric Optical View

Overall Optical View

Sample Caching Tube

CT Acquisition Parameters

24mm OD, 147mm long

170 kV / 100 µA

0.02” Copper Filter

7.5FPS, 5 frame averaging

voxel size: 15.2 µm

Geometric magnification: 8.17 X

Number of individual radiographs: 21,600

VorteX (helical) scan mode

7hr 12min scan time

Mounted w/ carbon fiber post + hot glue

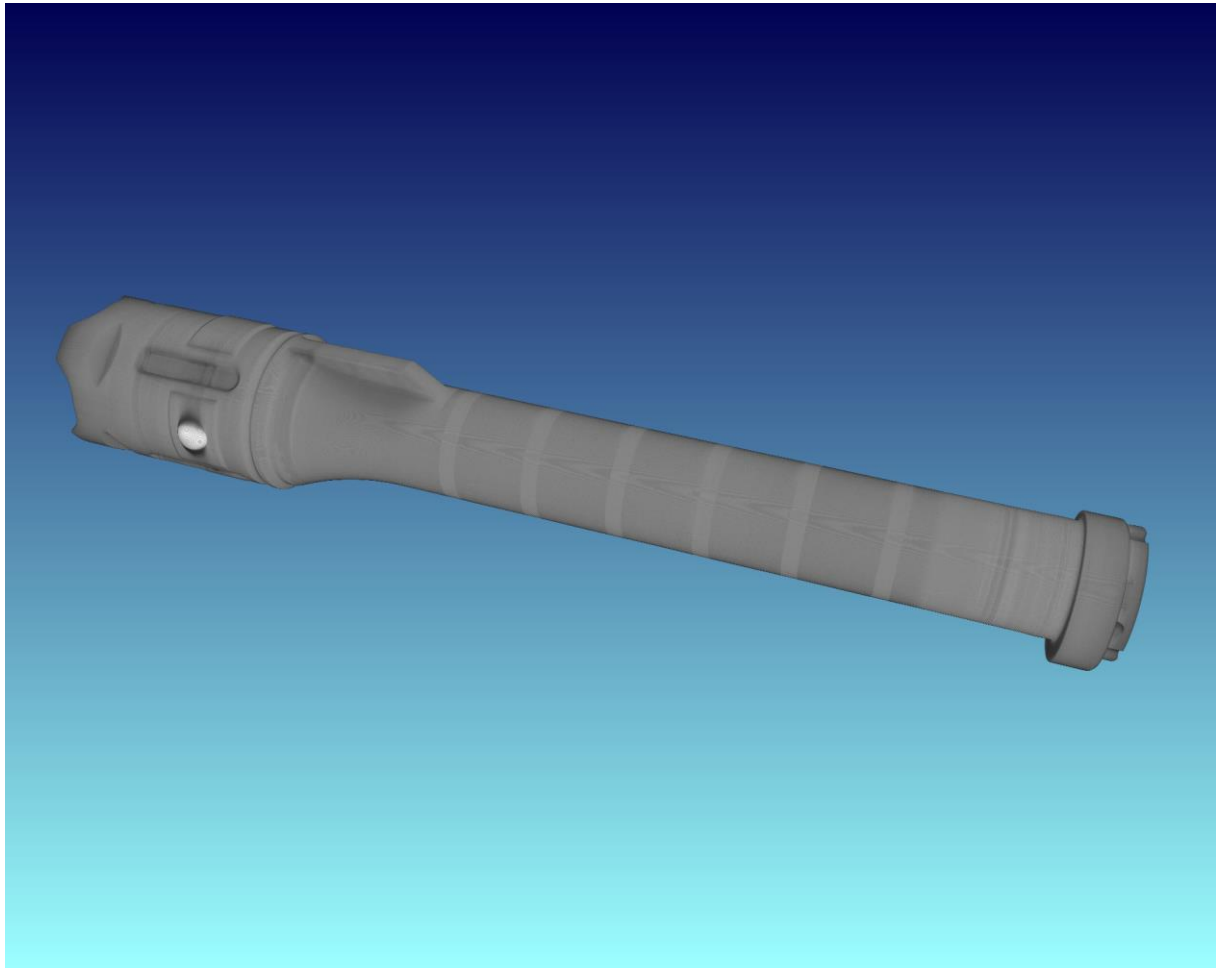
238 GB of radiographs

108 GB reconstructed

Sample Caching Tube

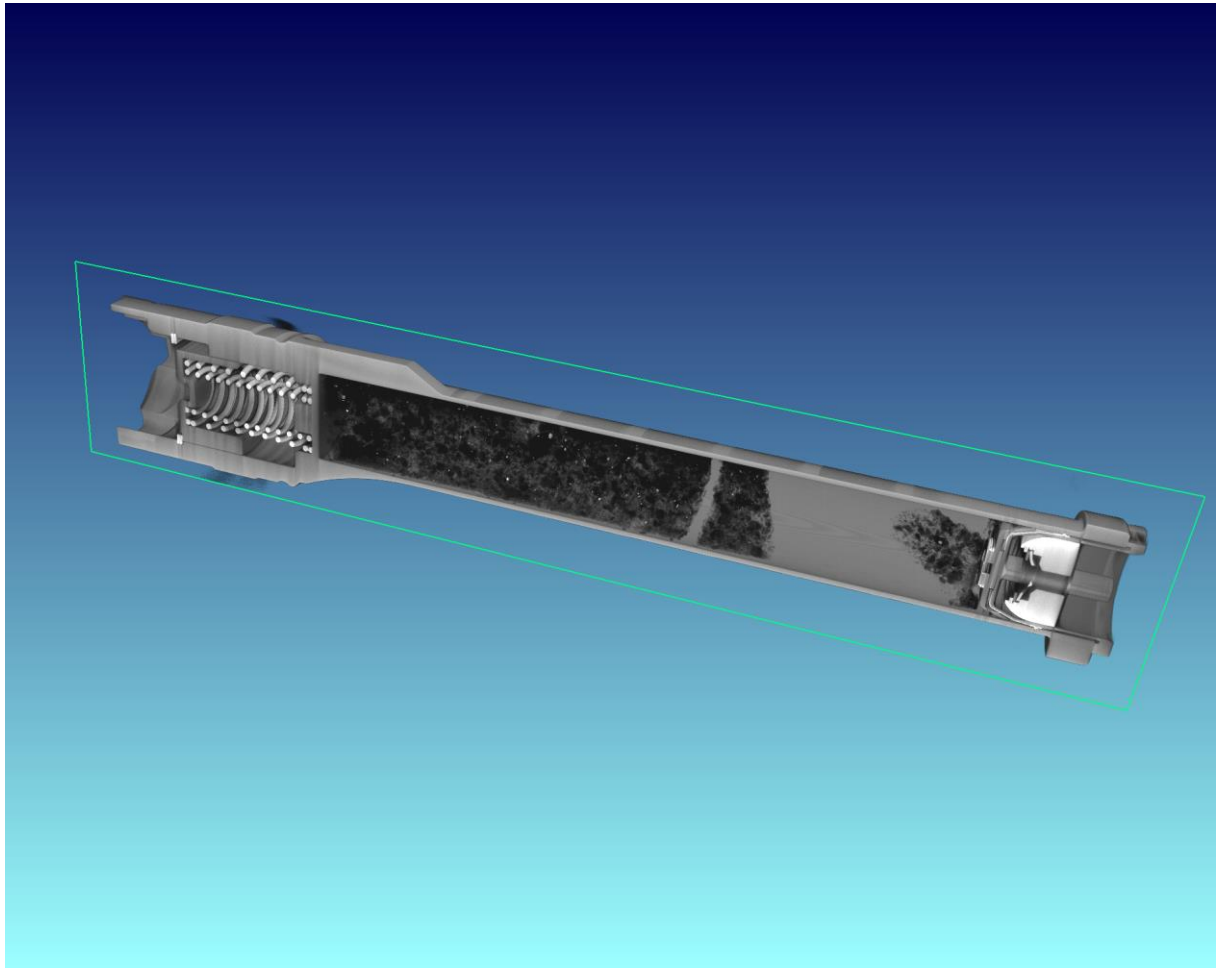
CT Dataset Overview

3D view



Overall view of Sample Tube exterior

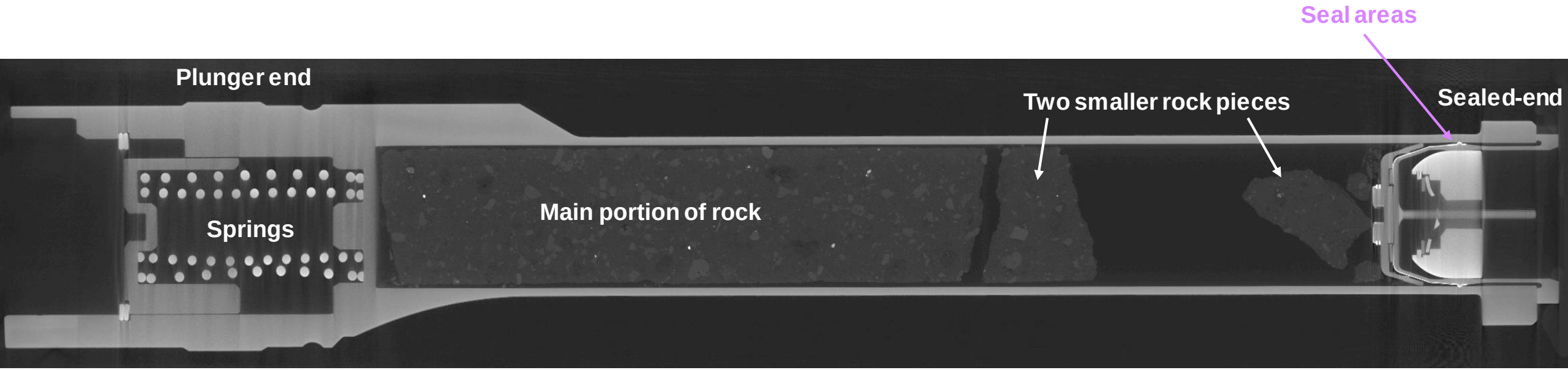
3D view with clip plane



Clip plane exposes rock sample inside

Sample Caching Tube

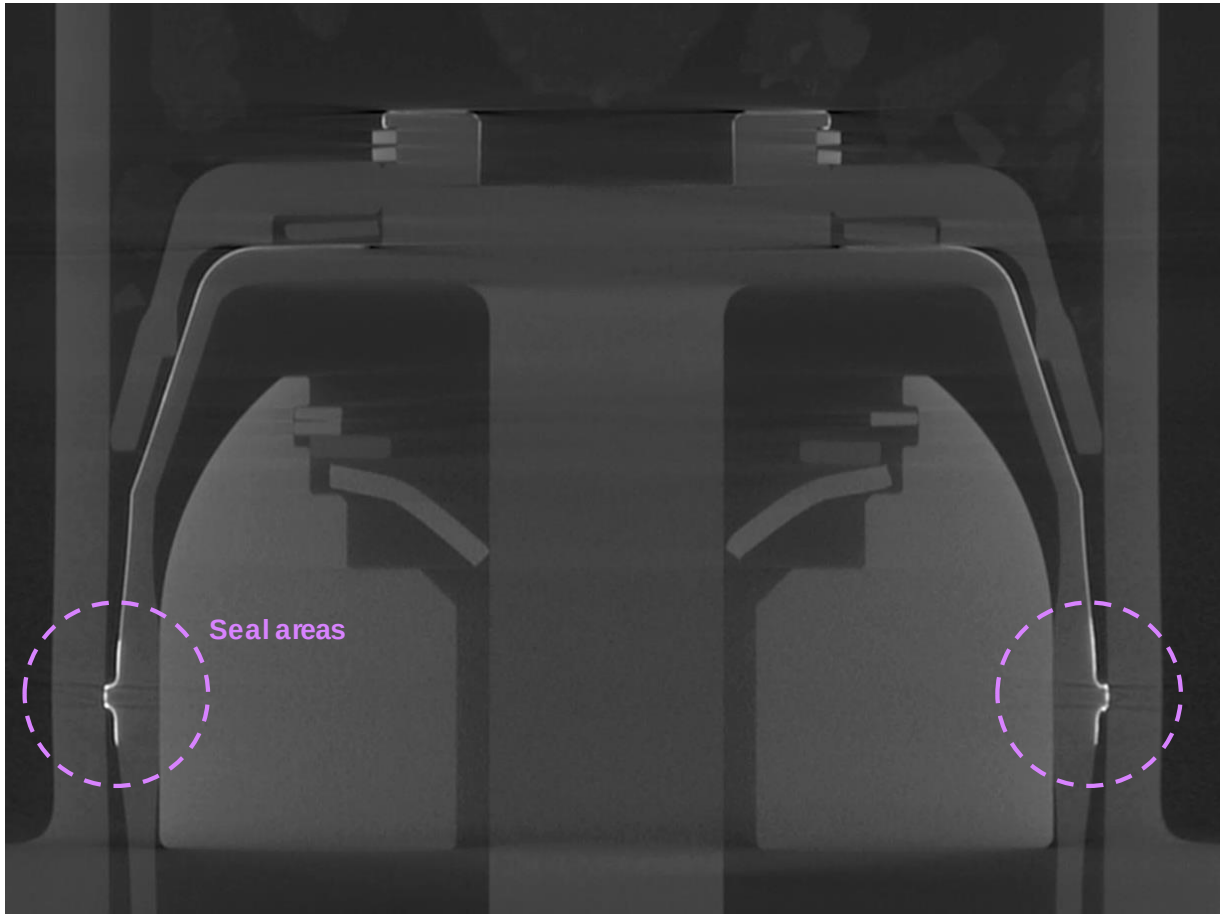
CT Slice View



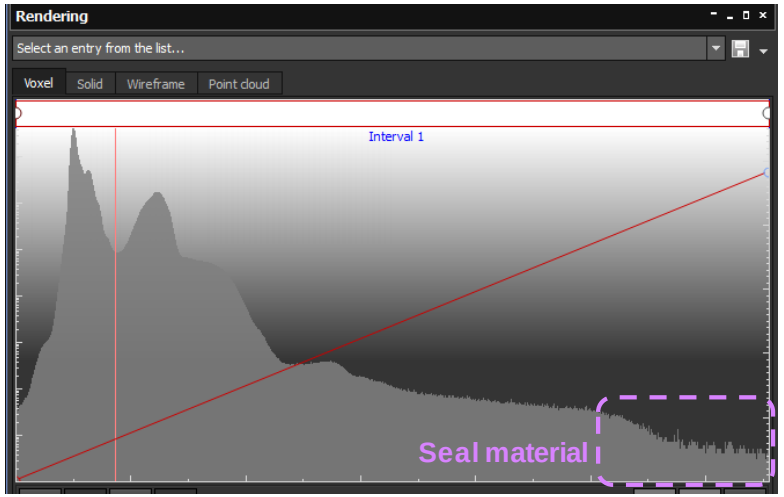
Sample Caching Tube

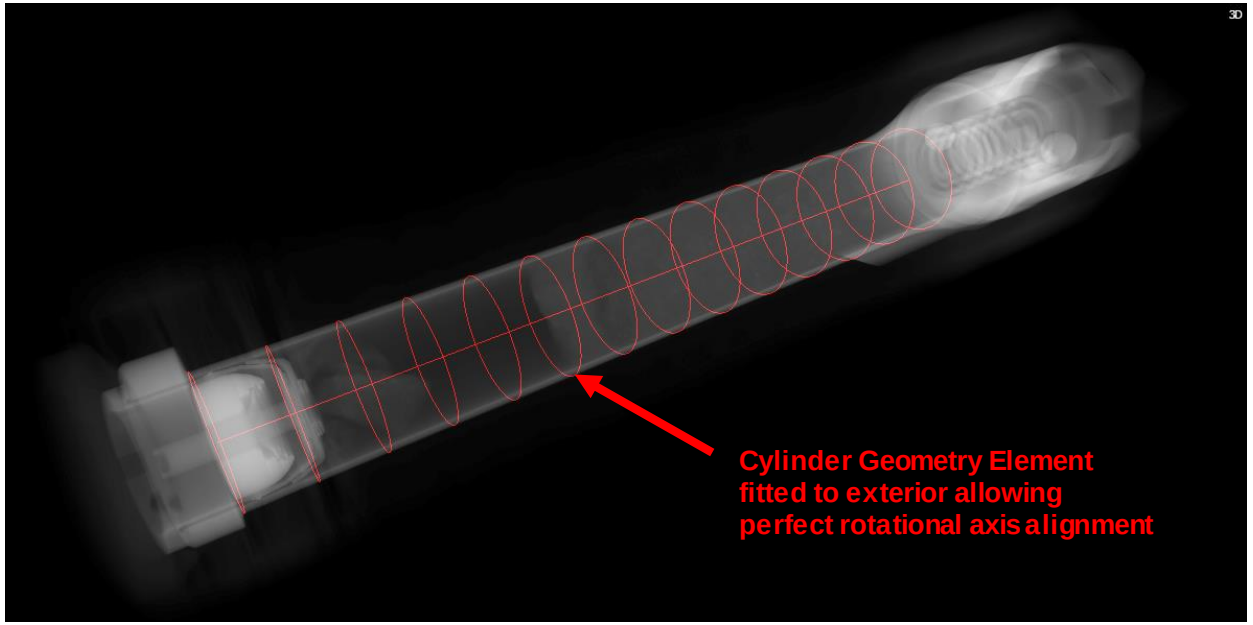
CT Data: Closeup on Seal

2D X-axis Cross-Sectional View



Overall view of the sealed end of the sample tube. The image appears darker to avoid saturating the seal material which is comparatively high density.

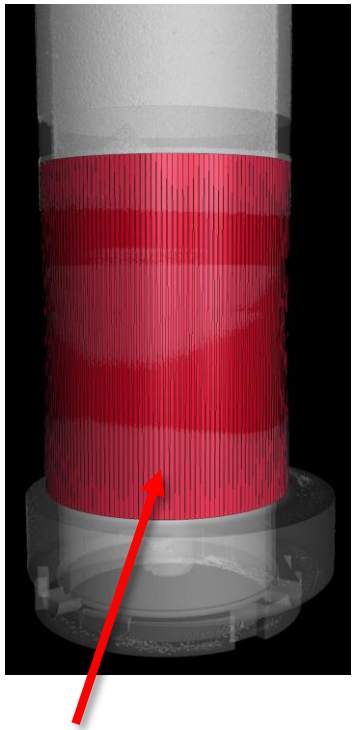




In order to avoid saturating seal materials, the correct histogram range (top) must be set during the import step. In order to establish a wobble-free rotational axis, a cylinder geometry element was fitted to the exterior (lower image).

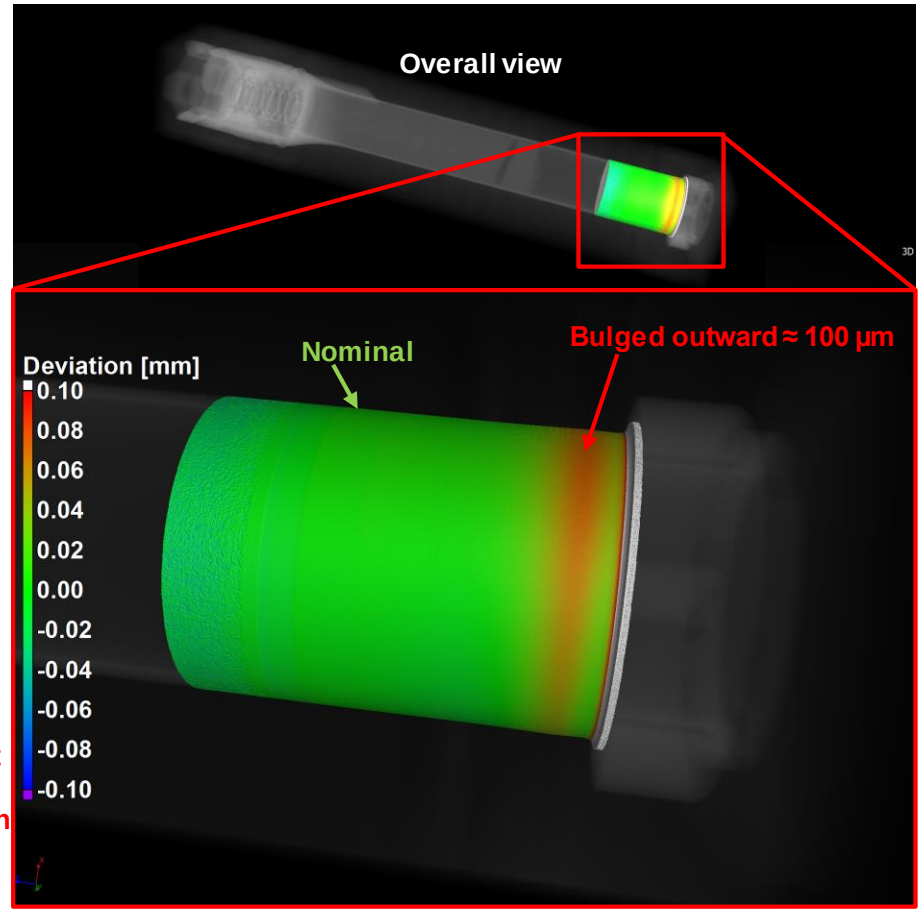
Sample Caching Tube

Nominal-Actual Analysis on Outer Diameter (Bulge from Seal)



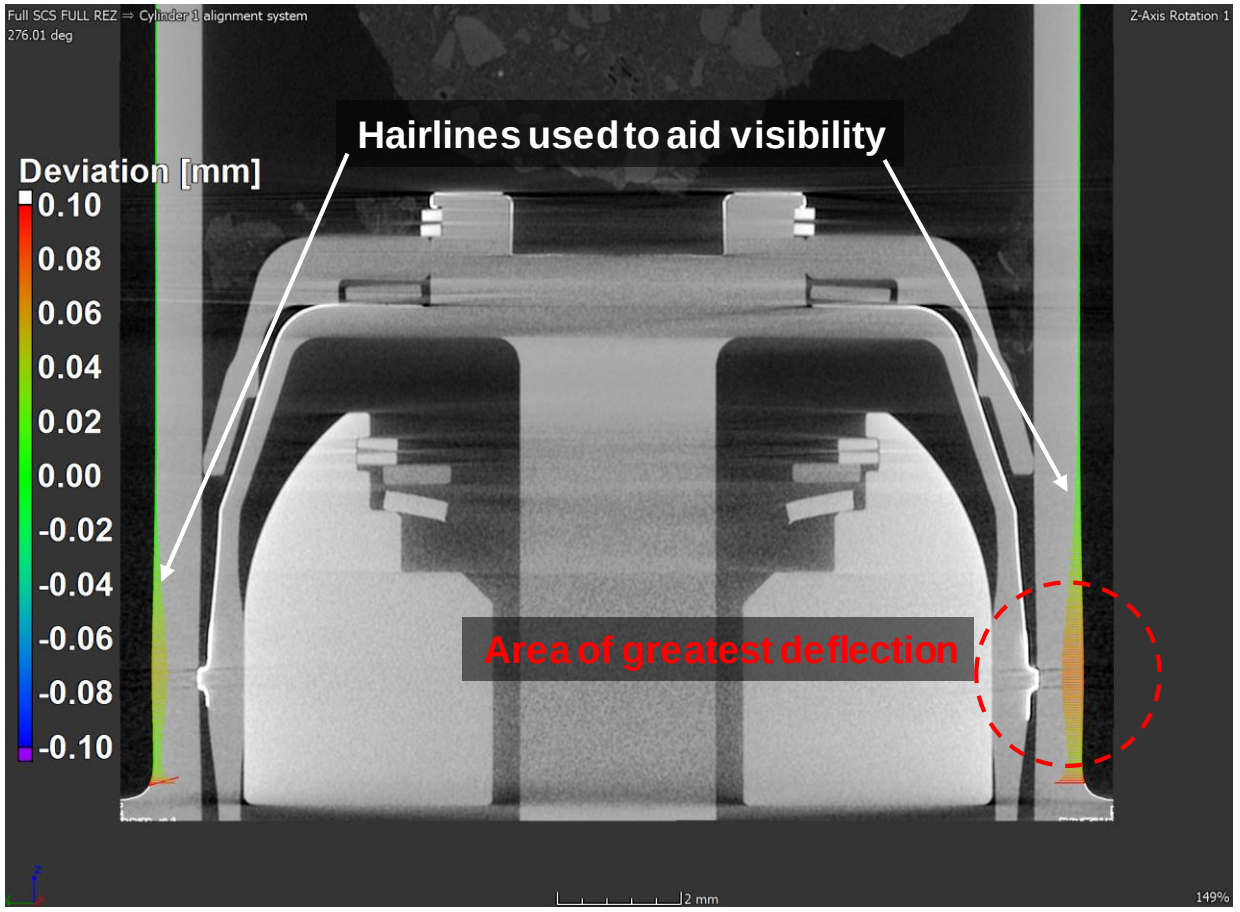
Cylinder Geometry Element Converted to mesh for Nominal-Actual Comparison

Post-Processing 3D View



In this image the deviation from a perfect cylinder of 7.43mm diameter is shown, to visualize the outward bulging of the Tube OD in proximity to the seal. An inset overall view is shown for context.

Post-Processing 2D Cross-Sectional View

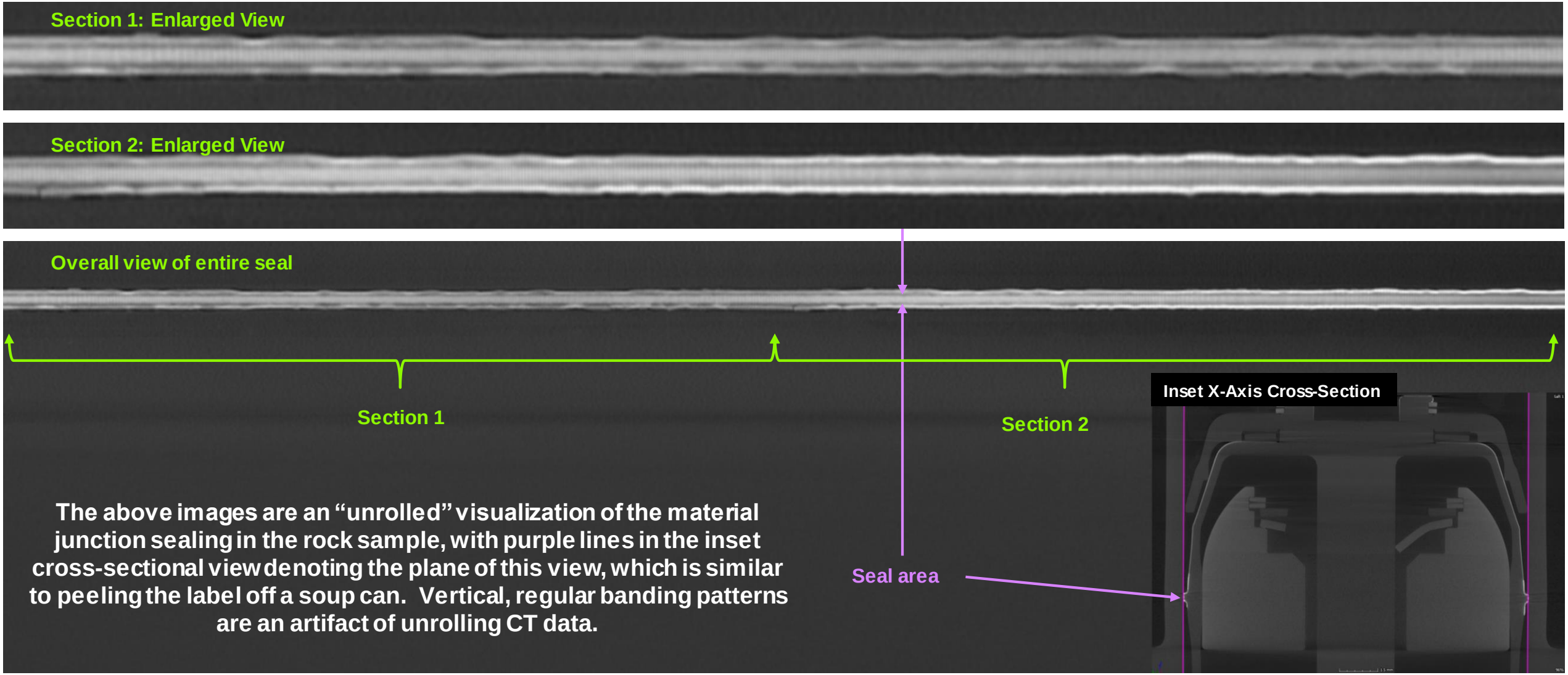


A 2D cross-sectional view of the same area is shown for perspective with the area of greatest bulging noted. Outward deflection of this area is expected as a byproduct of the sealing process.

Sample Caching Tube

"Unrolling" of Seal Interface

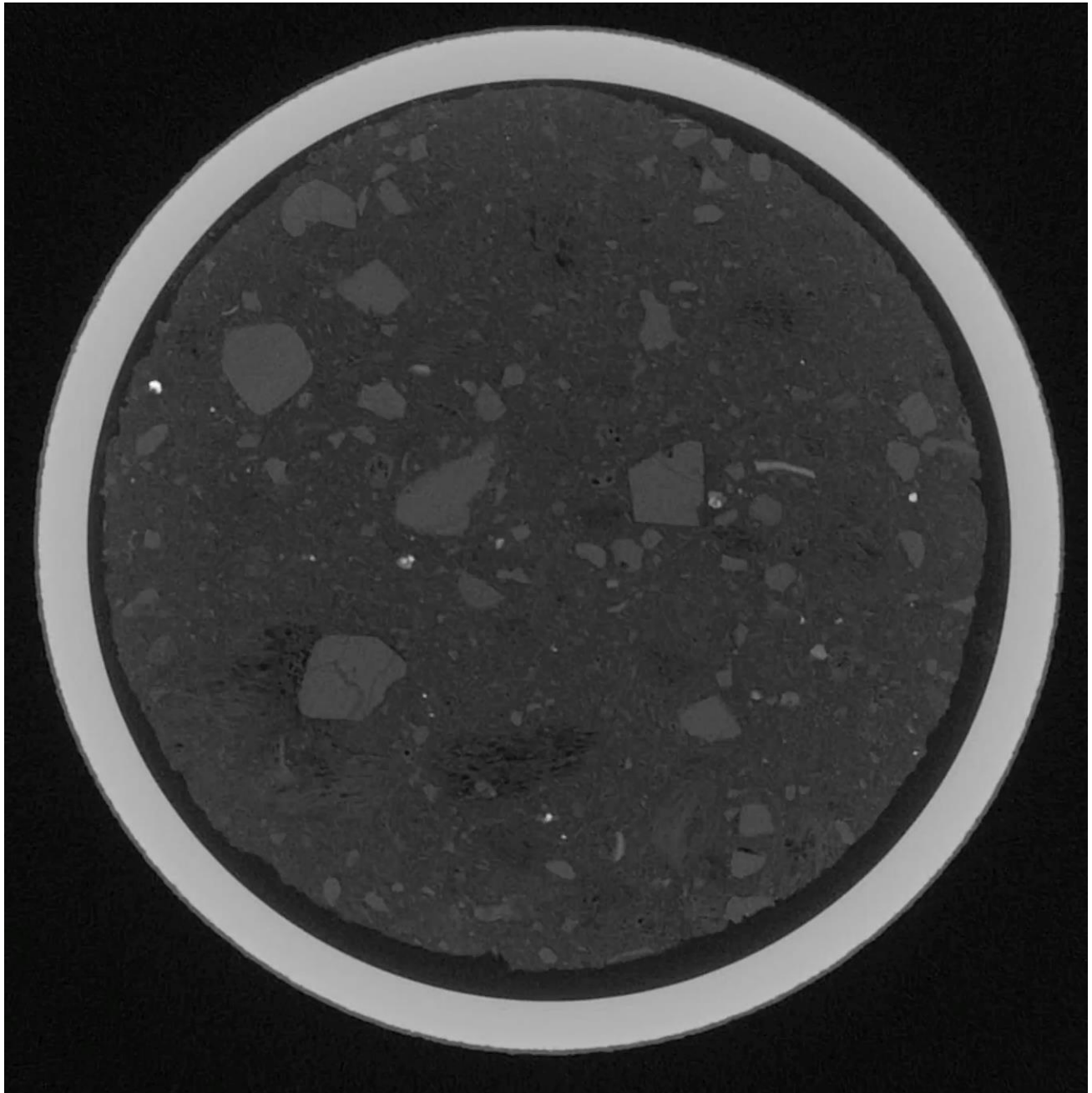
Non-Planar View in Unroll Mode:



The above images are an "unrolled" visualization of the material junction sealing in the rock sample, with purple lines in the inset cross-sectional view denoting the plane of this view, which is similar to peeling the label off a soup can. Vertical, regular banding patterns are an artifact of unrolling CT data.

Sample Caching Tube

Slice Video



Sample Caching Tube

Segmentation Workflow

Establish Sample Chamber ROI

- “Take From Existing” geometry element: exterior cylinder
- Adjust radius, height to match chamber
- “Extract ROI” to view the rock exclusively

Define Rock vs Empty Space

- Gray Value Selection Tool captures airspace
- Opening/Closing cleanup operation iteratively to remove voids within rock
- Invert resulting ROI to capture rock instead of air

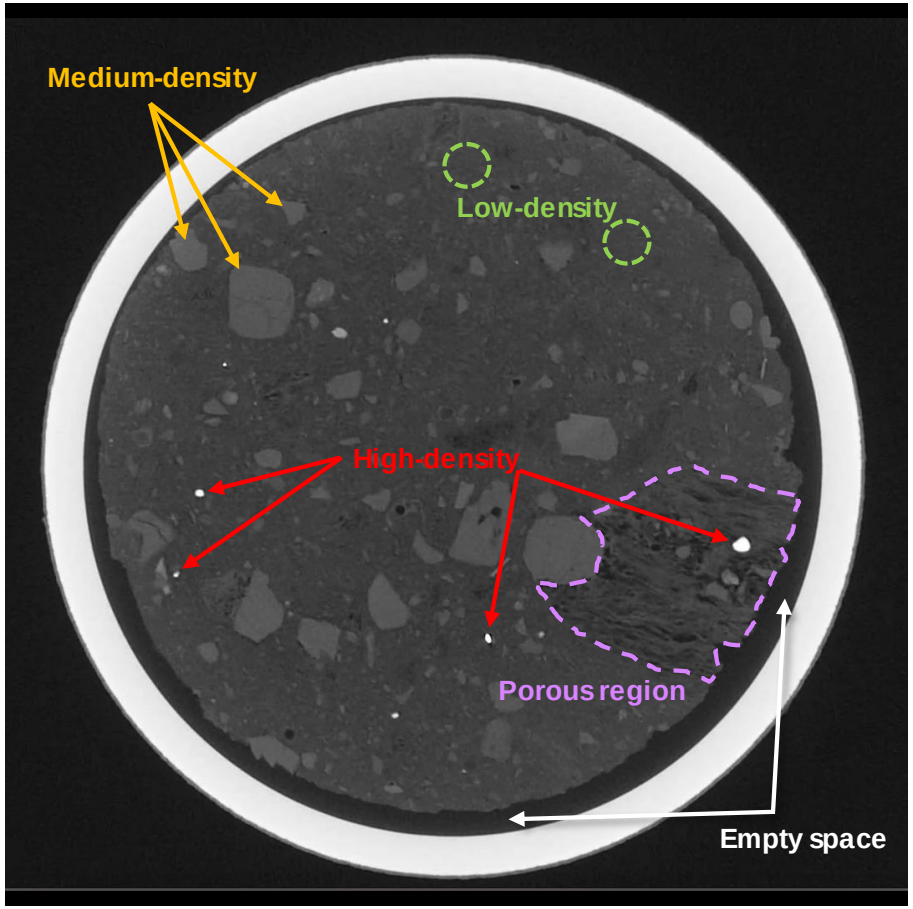
Segment Rock Densities

- Gray Value Selection Tool to highlight density ranges of interest
- Luckily no major streak artifacts, which would present a challenge
- “Use Defect ROI” for quantitative analysis on specific density

Sample Caching Tube

Segmentation of Rock Sample

2D X-axis Cross-Sectional View



A representative slice of the rock is shown, with annotated examples of the different densities which were quantified by post-processing this data.

Quantification of Rock Types

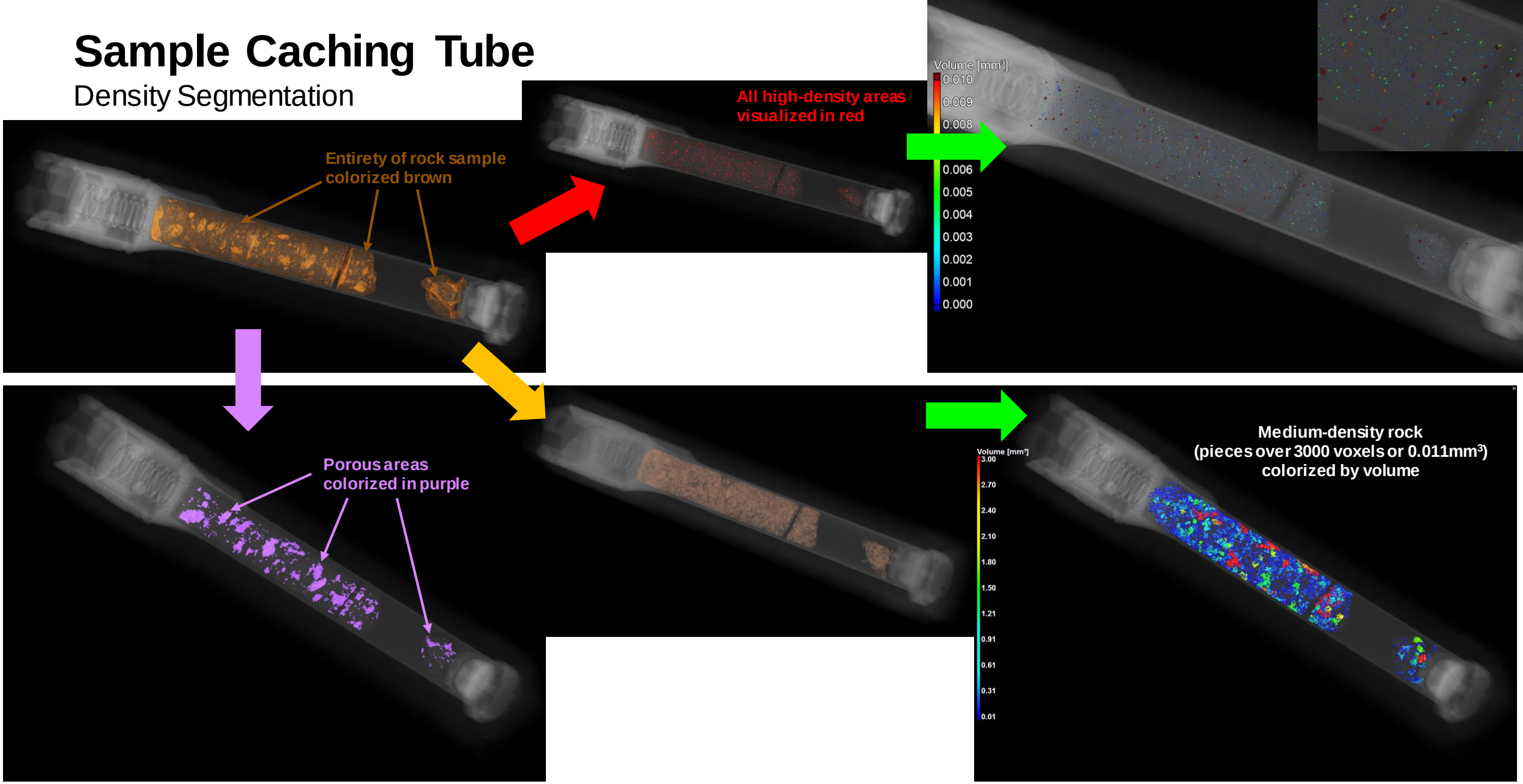
	mm^3	percent
Internal Tube Space available for Rock Sample:	13,057	
total volume of rock sample taken:	8,357	64.0%
total volume of low-density rock:	7,277	87.1%
total volume of medium-density rock:	817	9.8%
total volume of porous regions:	255	3.1%
total volume of high-density rock:	7.4	0.1%

Percentage quantification values are given in the table above.

Note that 64% signifies the available internal tube space which is occupied by rock. The remainder of percentages given relate to the volume of rock, not the total internal volume of the Tube.

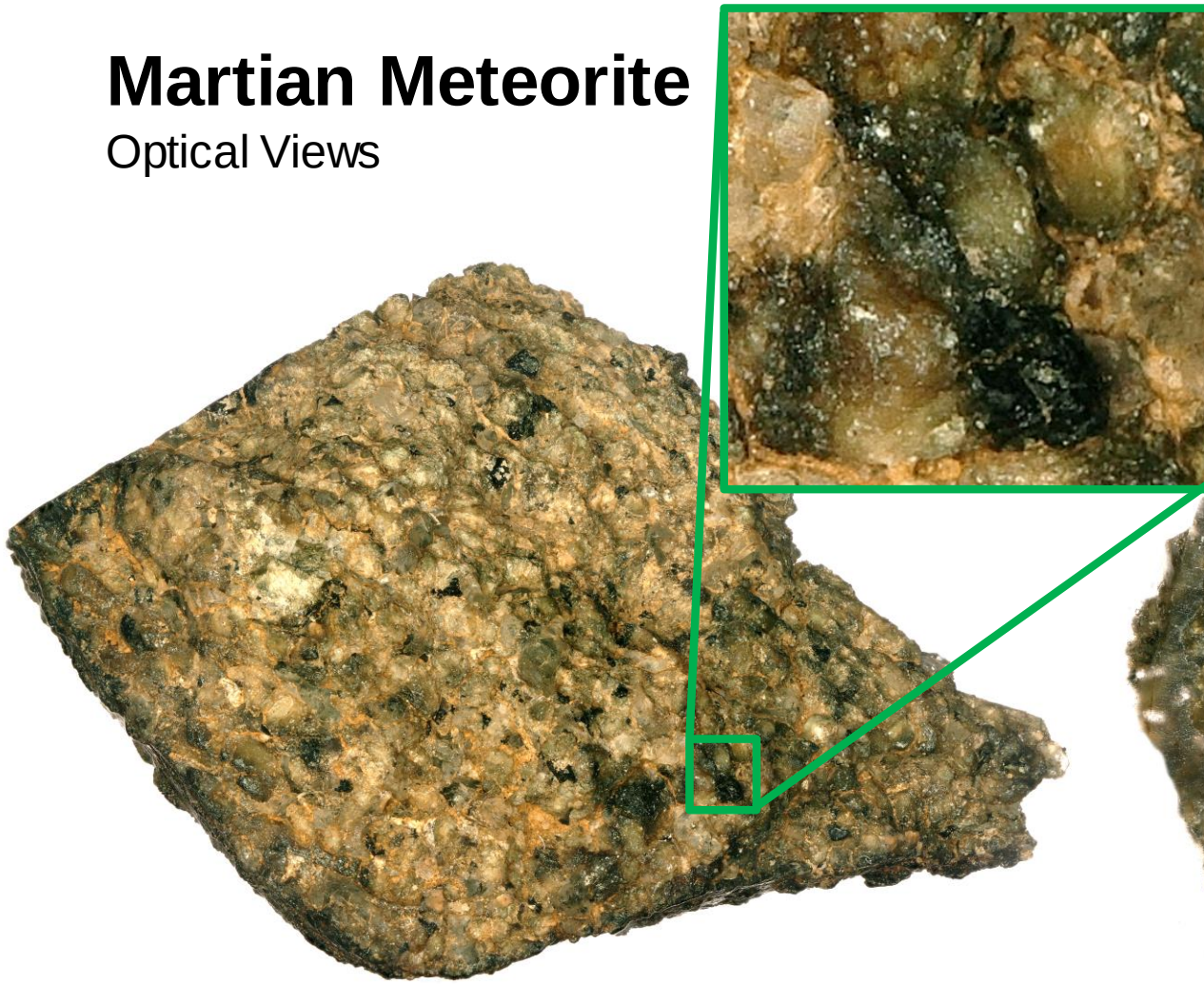
Sample Caching Tube

Density Segmentation

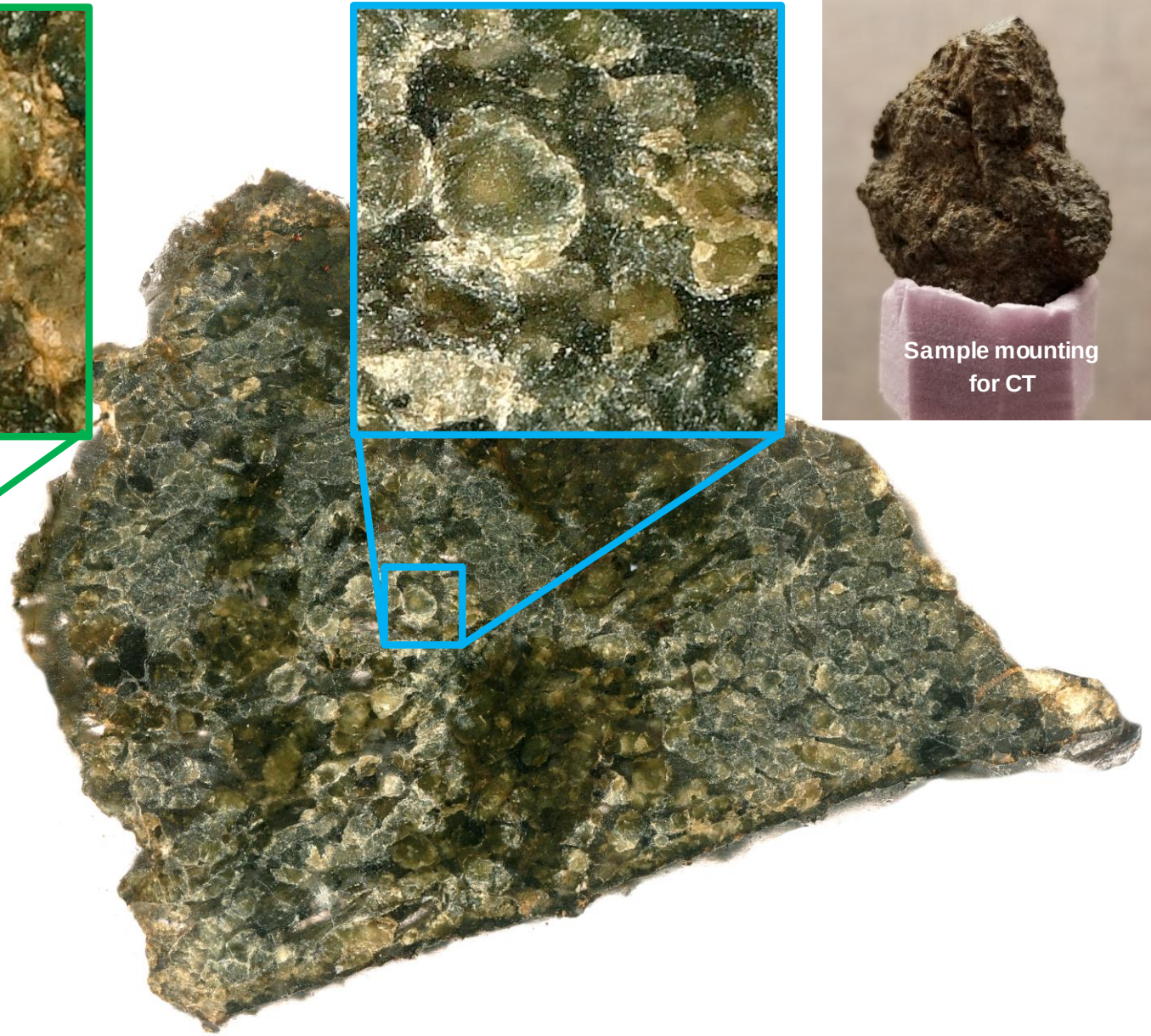


Martian Meteorite

Optical Views



Overall optical view of uncut-face on Martian meteorite sample NWA-TBD



Optical view showing physical cross-sectioned plane

Martian Meteorite

Optical Views

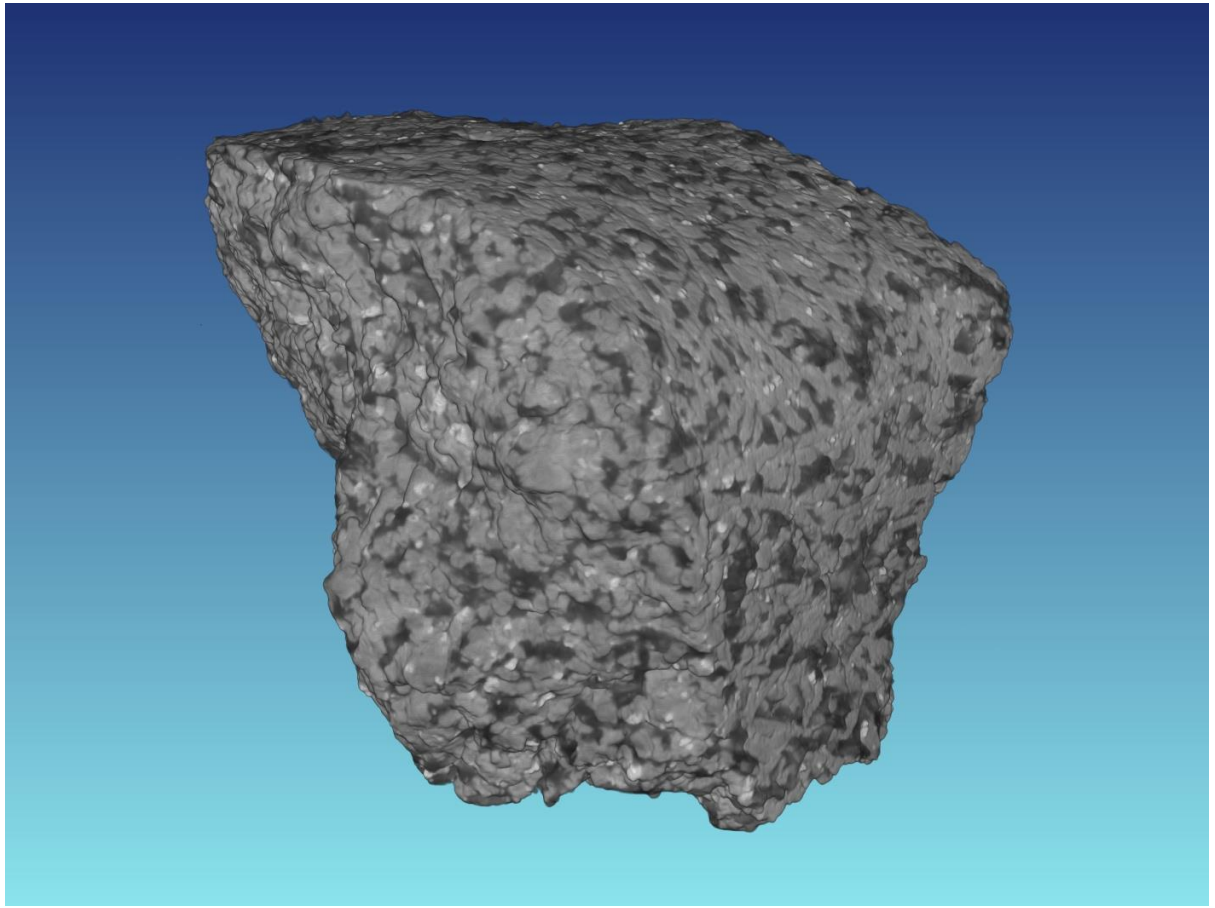
Overall optical view of opposite uncut-face on Martian meteorite sample NWA-TBD

Optical view showing physical cross-sectioned plane using polarized light to highlight cracks

Martian Meteorite

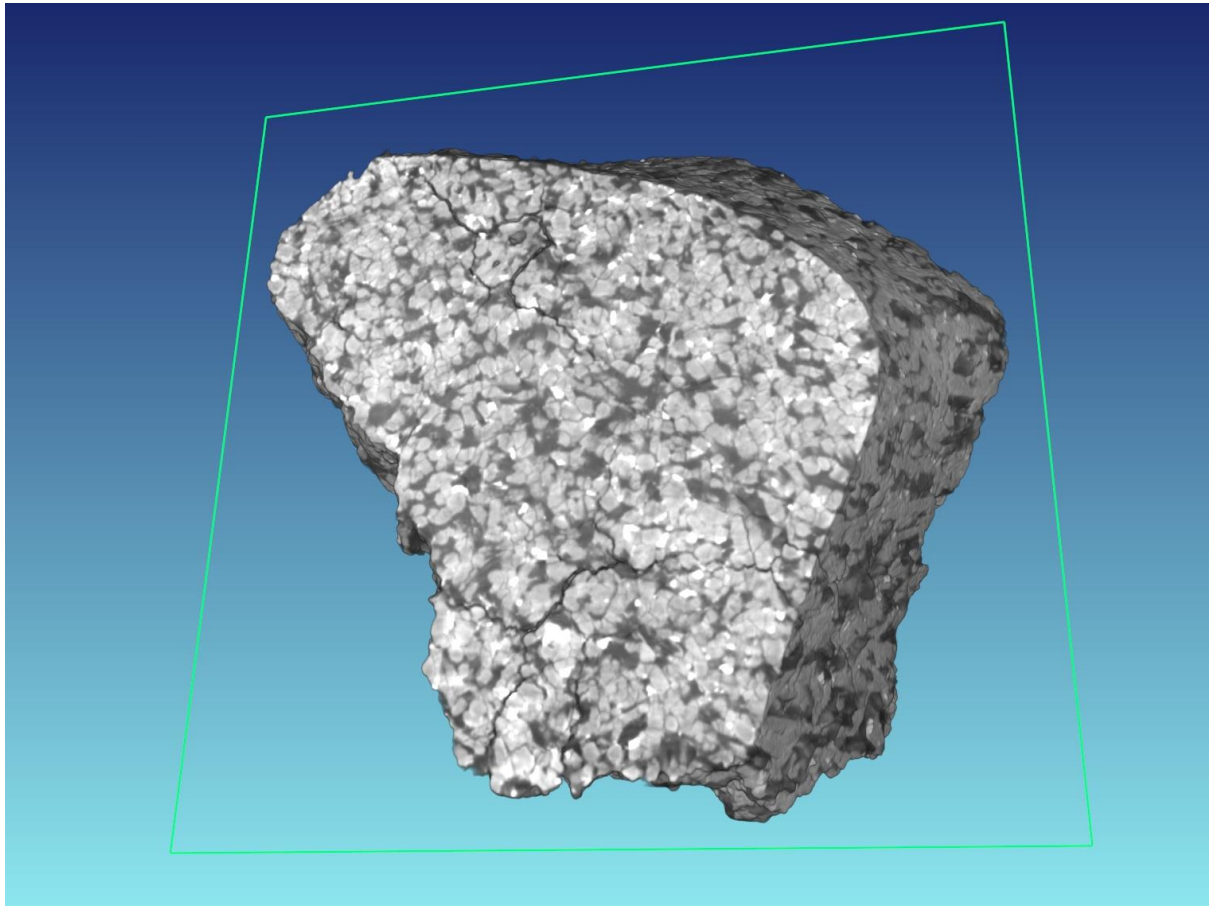
CT X-ray Overall Views

NWA-TBD, 3D View



Overall 3D view of the entire meteorite with all densities shown. Voxel size of this dataset is 10.7µm.

NWA-TBD, 3D View

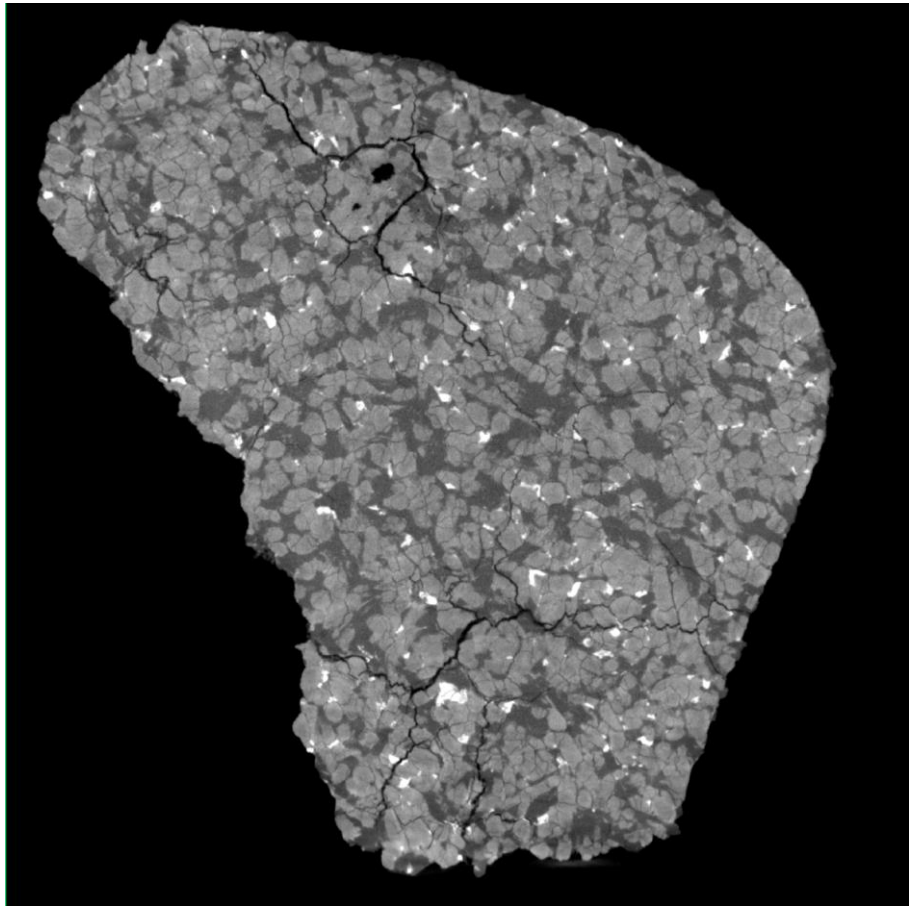


Overall 3D view of the entire meteorite with clip plane exposing the interior of the sample.

Martian Meteorite

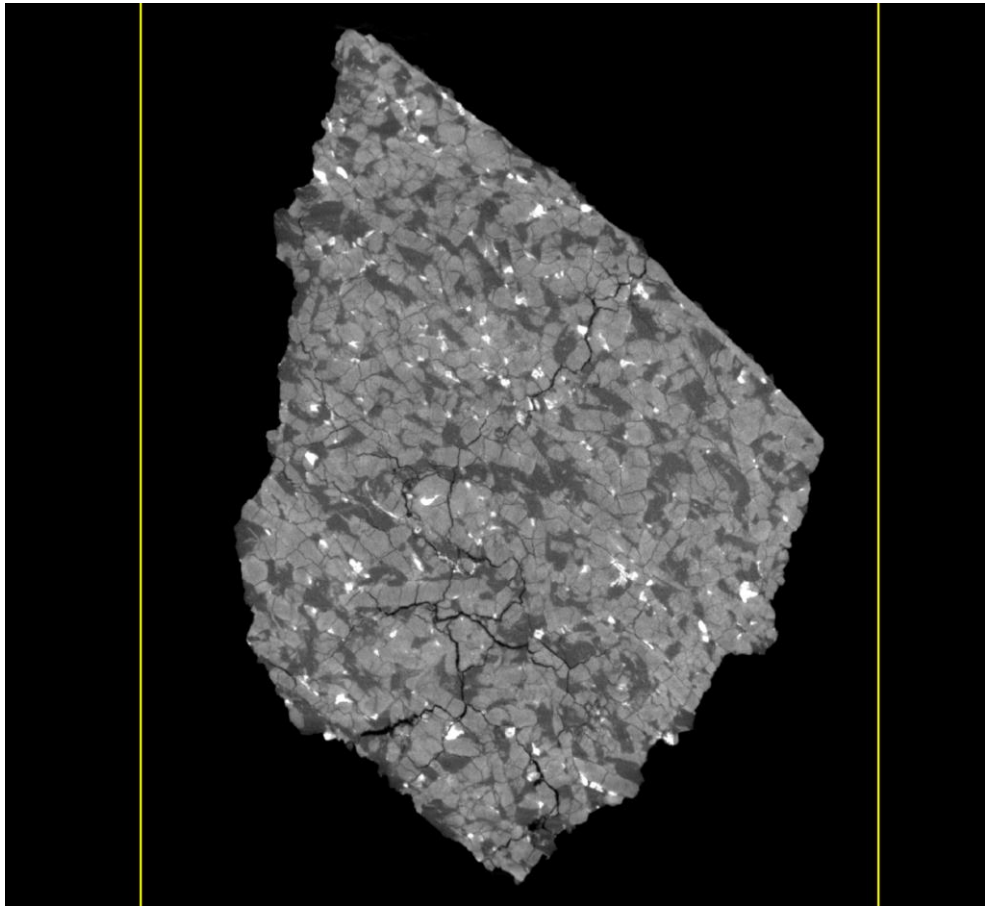
CT X-ray Slice Views

NWA-TBD, 2D View



Overall 2D Cross-Sectional view of the meteorite, showing various density materials.

NWA-TBD, 2D View

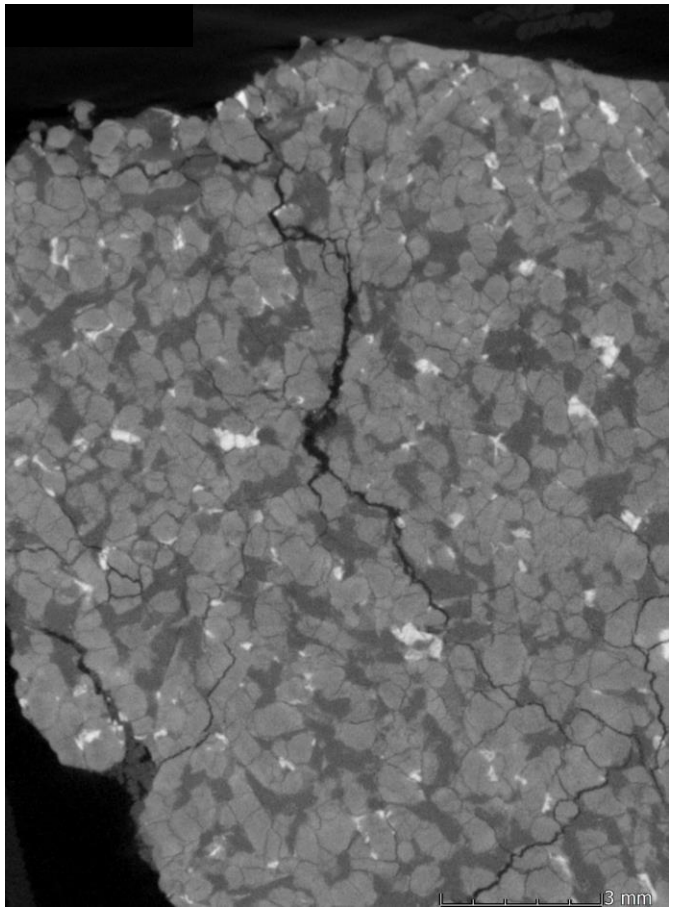


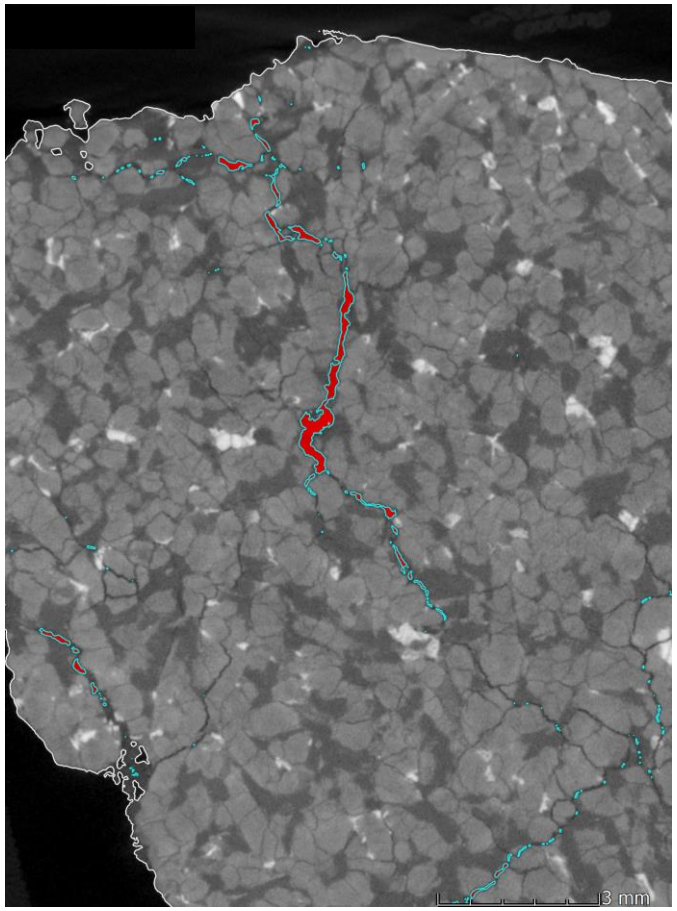
Additional overall 2D Cross-Sectional view of the meteorite, set 90º apart from the image at left.

Martian Meteorite

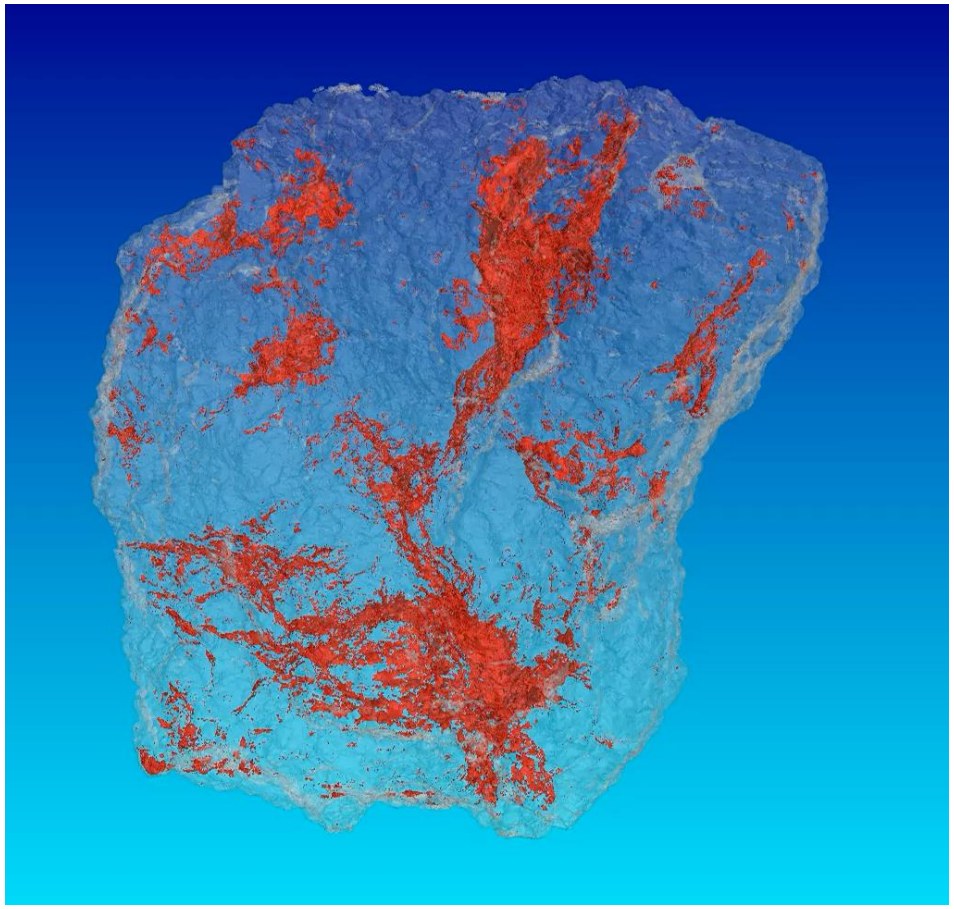
Crack Visualization

NWA-TBD, 2D Views





3D Crack Visualization



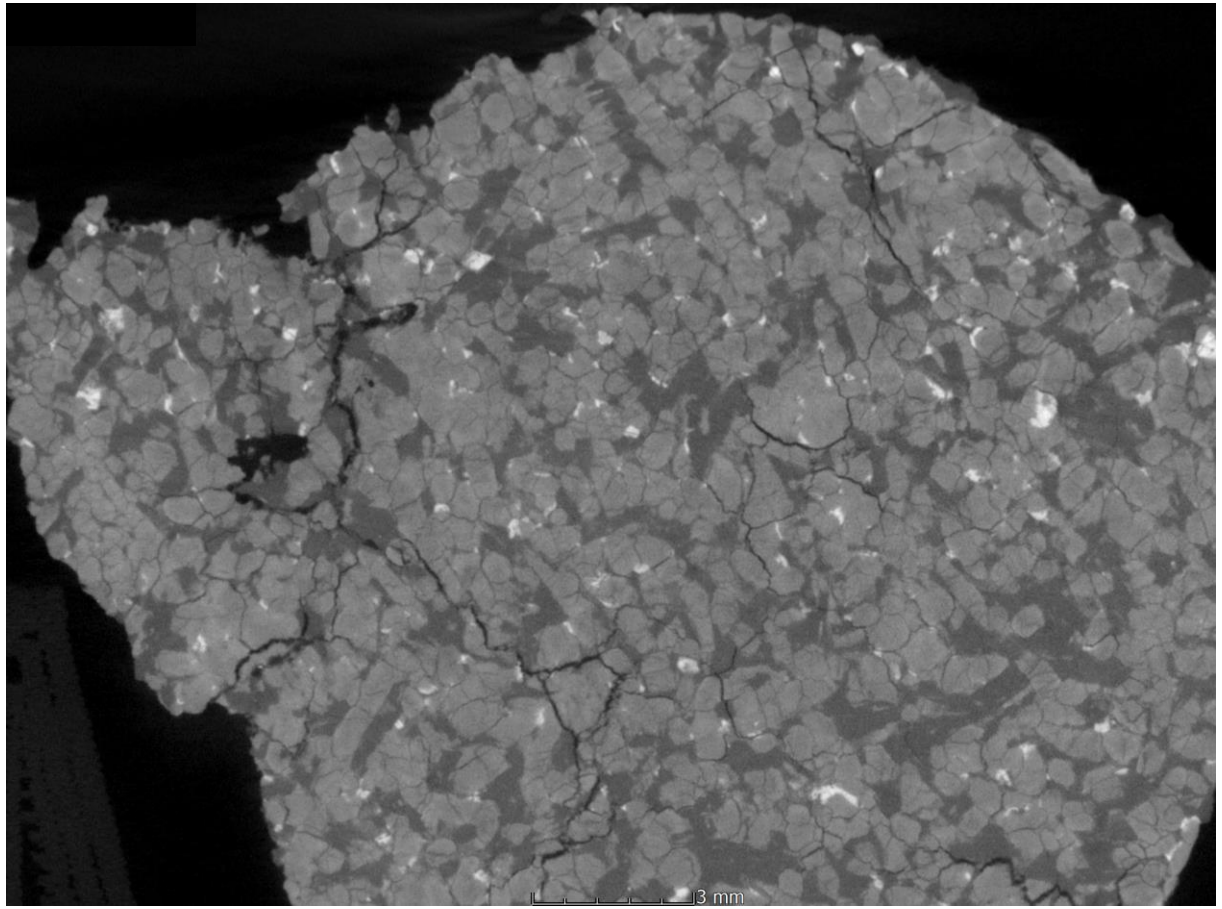
Closeup 2D Cross-Sectional views of the meteorite, showing various material densities and cracks (airspace). The largest cracks have been segmented and colorized red. A 3D Visualization video is shown at far right.

Non Destructive Evaluation

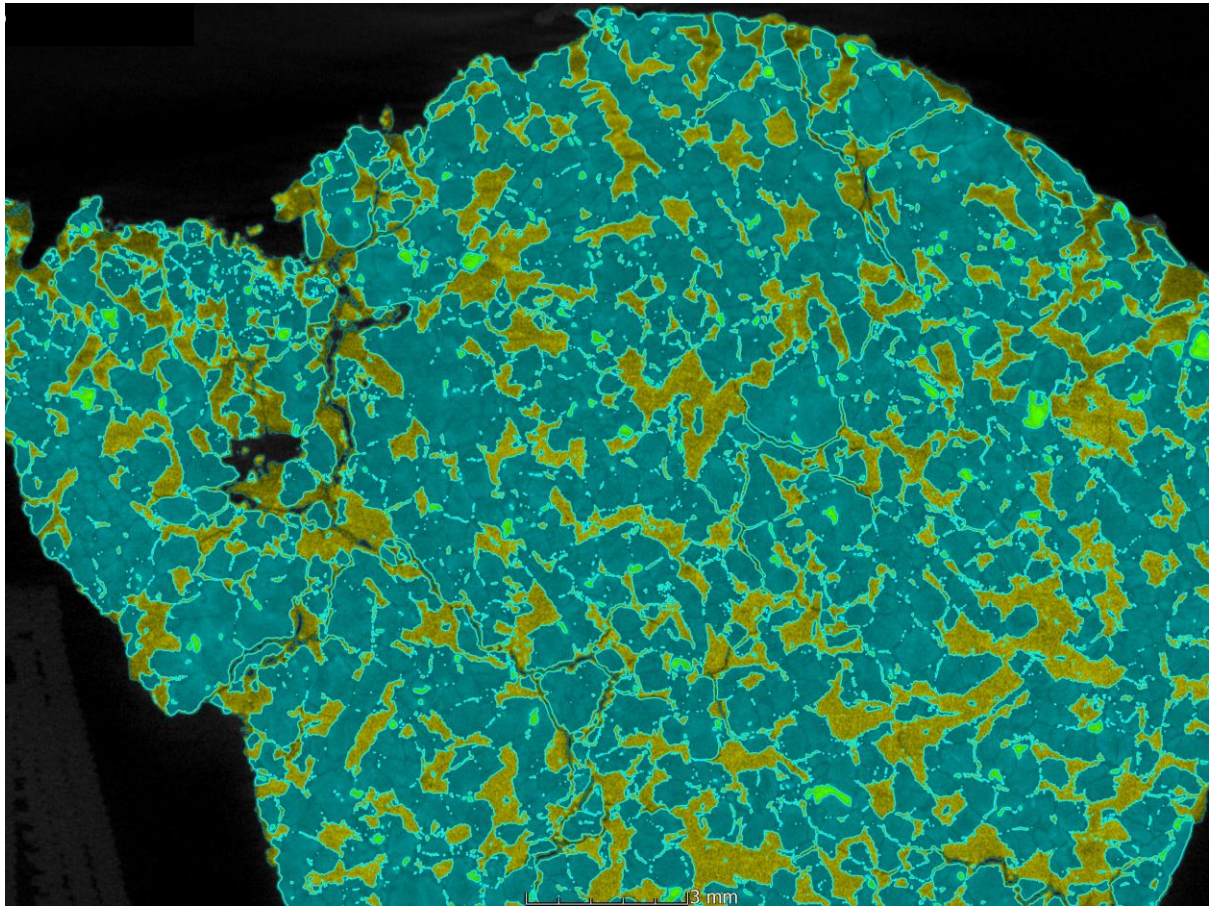
Density Segmentation

	mm^3	percent
total volume of (NWA-TBD) rock sample:	4,546	
total volume of low-density rock:	1,313	28.9%
total volume of medium density rock:	3,145	69.2%
total volume of high density rock:	69	1.5%
total volume of airspace:	16	0.4%

NWA-TBD, 2D View



Closeup 2D Cross-Sectional view of the meteorite, showing various material densities and cracks (airspace).



The same image from left has been analyzed above: low-density areas are blue, mid-density is yellow, high density is green, and light blue lines denote the boundaries between each. Quantitative results are shown at top right.

Jet Propulsion Laboratory
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